Scale Versus Detail in Water-Rock Investigations: Integrating geologic models with hydrogeochemical studies.

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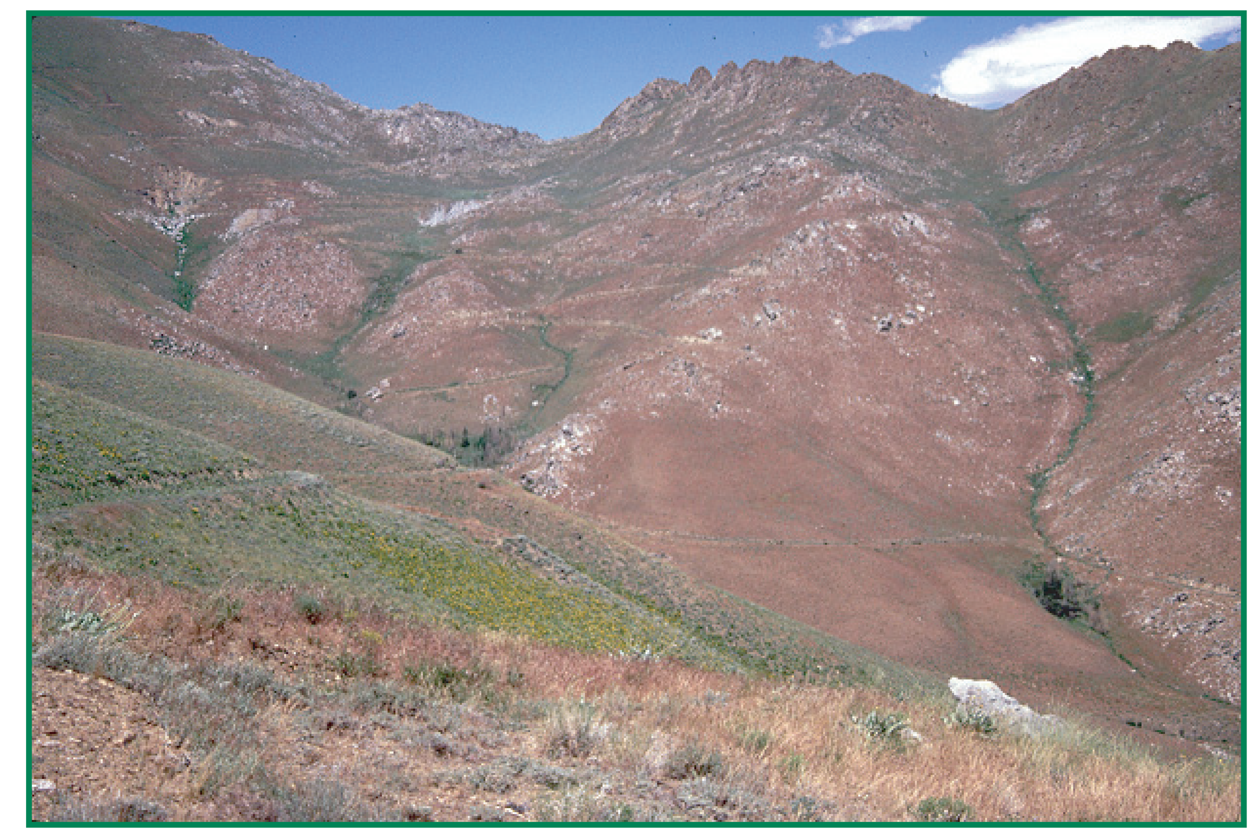
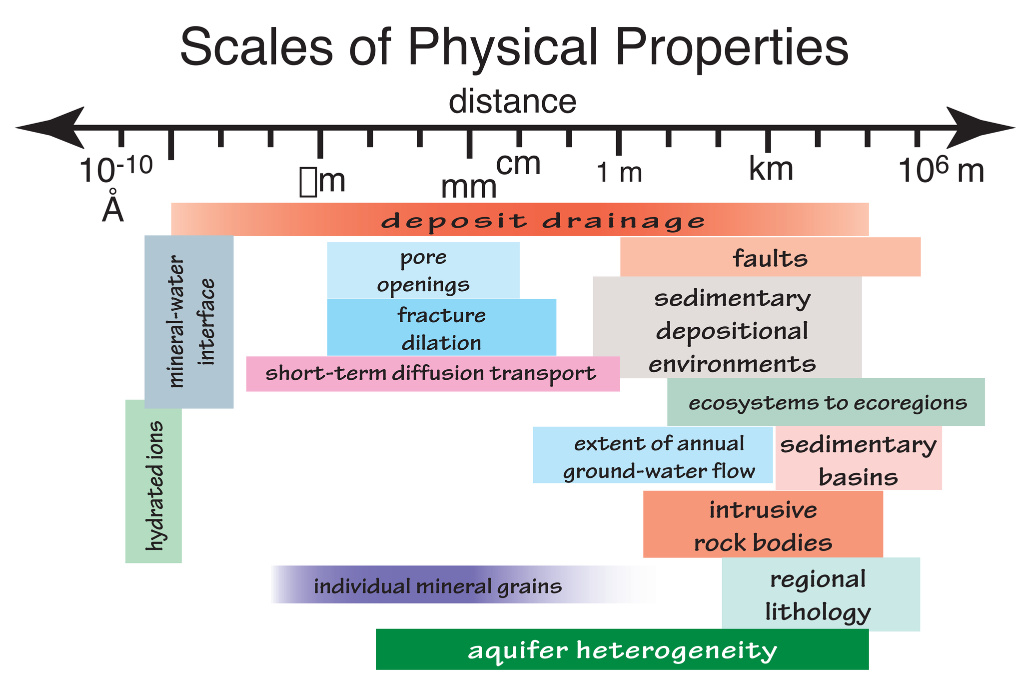
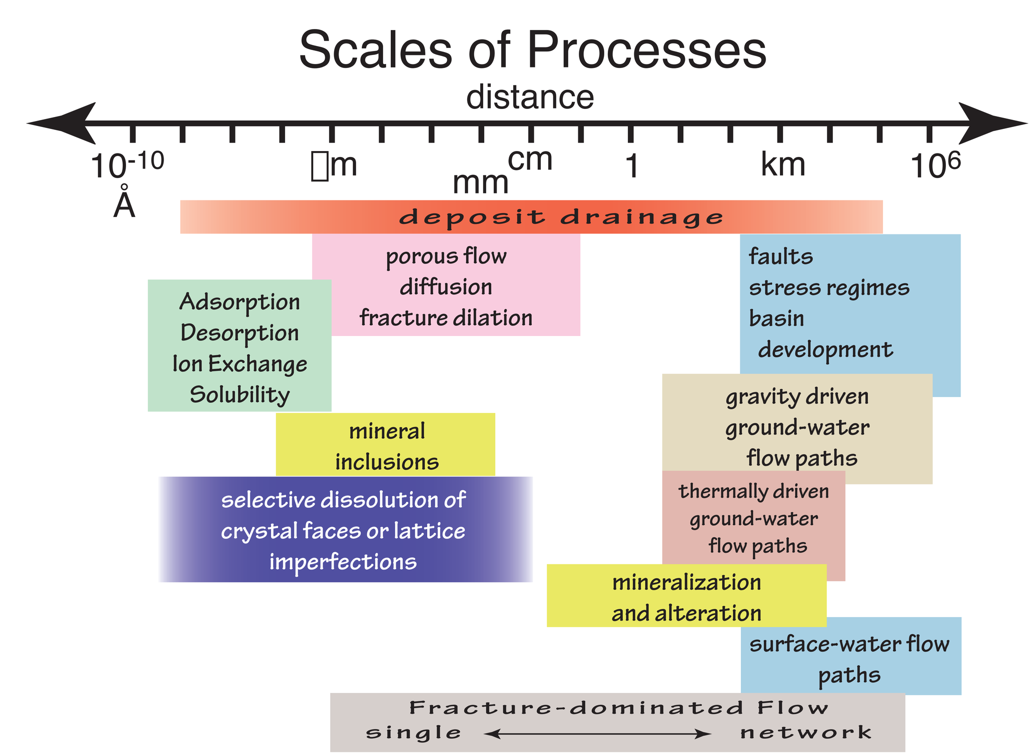


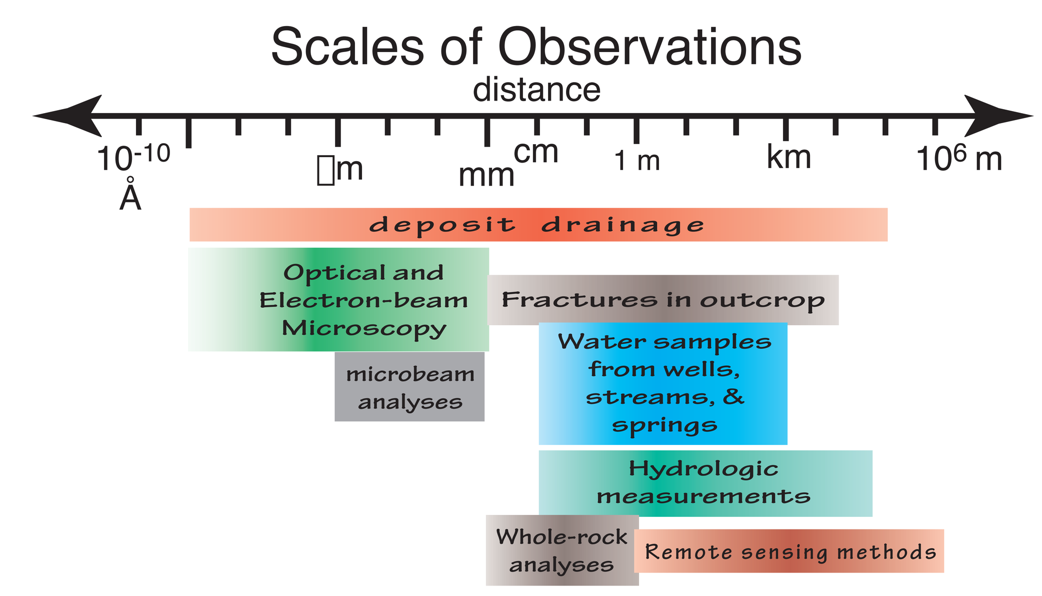
The problem:

Studies of natural systems must be conducted in a way that balances research funds with the level of detail necessary to understand the system. Thus, the scale of the study must be balanced against the required detail. We have developed a framework for performing studies of natural systems that weaves geologic, hydrologic, and geochemical information. The most important feature of this approach is the constant interplay between scientists of each specialty, so that the field work produces the most representative results possible.

We begin by examining the spatial scales over which system properties and processes are important, and compare those to the spatial scales over which our observations of the system are relevant. In this example, we are studying the geochemical effects of mineral deposits that may generate metal-rich drainage, so the top scale bar in each figure below is labelled "deposit drainage." We are concerned with mineral deposits occurring in fractured rocks; the fractures represent the principal conduits for fluid flow in the geologic past (deposit formation) and in the present (deposit weathering).

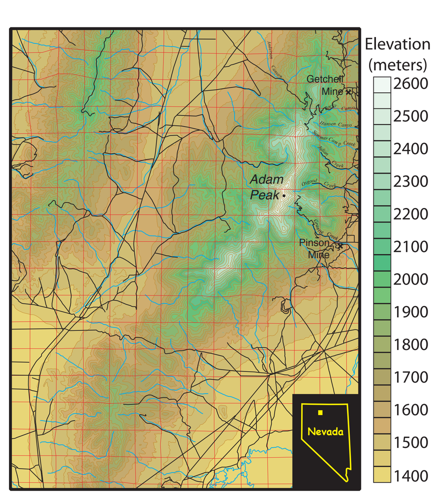






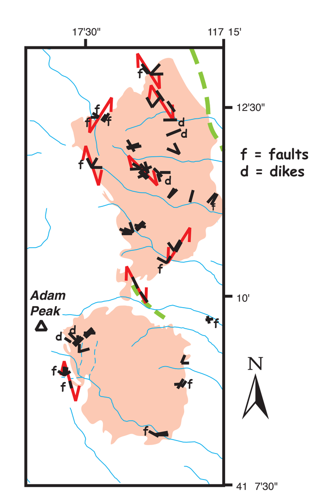
Developing a field strategy from a regional-scale geologic model:

Our approach to field work begins by formulating a geologic model that describes the tectonic history and fracture evolution in the study area. Our field area is in north-central Nevada, in the Osgood Mountains.

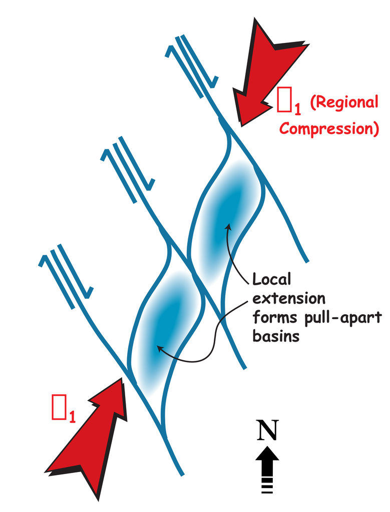


Climate in the Osgood Mountains is relatively dry, average annual precipitation is about 18 cm, and the average temperature in the valleys is 10 C, cooler at higher altitudes.

Two large granodiorite-composition intrusive bodies outcrop in the Osgood Mountains (shown in light tan on the map at right). The surrounding sediments were contact-metamorphosed and metasomatized, leading to the development of tungsten-rich skarn deposits. Within the intrusive bodies, there are zones of pyrite-rich hydrothermal alteration (Hotz and Willden, 1964).



We begin with field geologic observations of the orientations and kinematic indicators for fractures and faults. Our data showed three major fracture/fault orientations: a NNW set with right-lateral offset; a NE set with left-lateral offset, and an E-W set of structures including fractures and dikes.

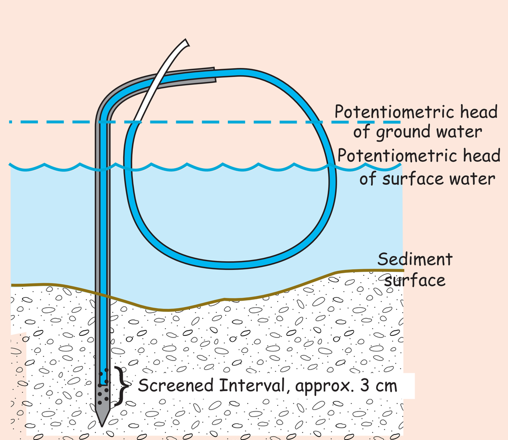


Our geologic observations are consistent with a model wherein regional tectonic compression leads to development of NW stiking, right-stepping, right lateral strike-slip faults, within which smaller pull-apart basins form. These pull-apart structures are zones of local extension and form a conduit into which magma can be emplaced.

Field results at a variety of spatial scales:

(information in colored boxes corresponds to locations on map in center)

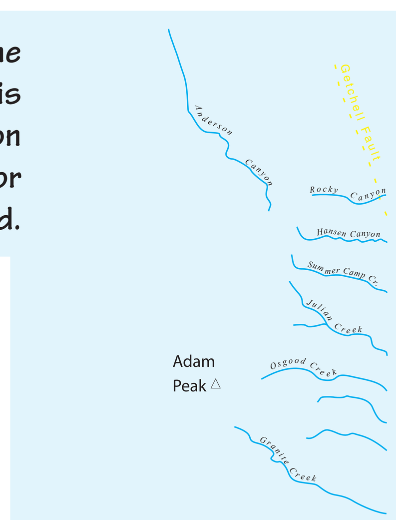
A



In the upper reaches of Granite Creek, NE-trending fractures in outcrop intersect the stream at the point shown in this photo. Hydraulic head measurements from 30 cm below the streambed showed this to be a losing reach, with approximately -15 cm of head relative to the stream surface. The geologic model predicts that the NE trending fractures should be hydraulically conductive. Head measurements are made using the device shown at left (Wanty and Winter, 2000).

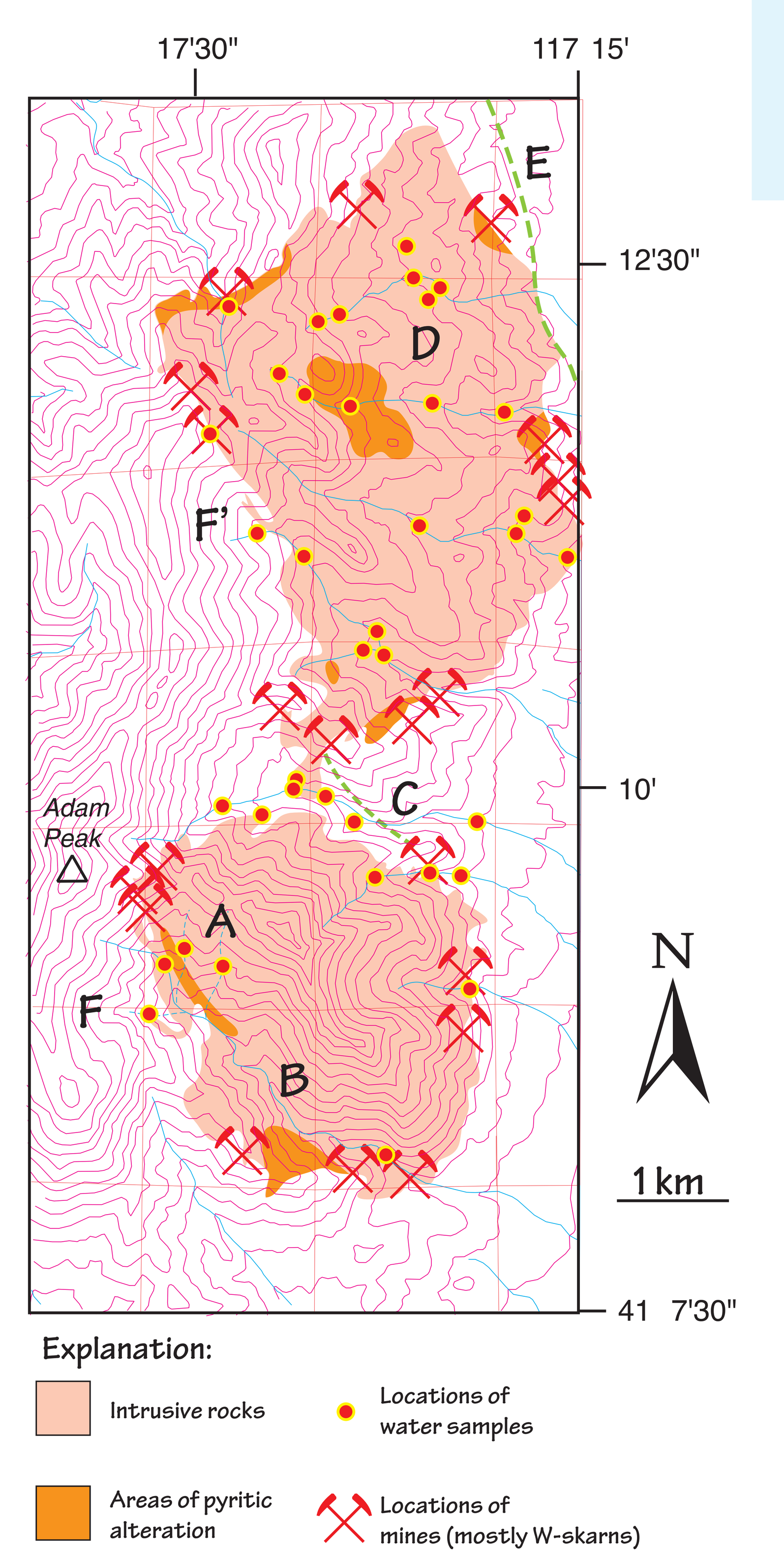
E

The surface expression of the Getchell Fault is clearly seen in this shaded relief image. Also shown on the figure to the right are the major streams we sampled.



D

This spring issues from a ridgetop above Rocky Creek. An east-trending dike with sheeted easterly fractures provided the conduit for this unusual flow. The dike is clearly seen in the aerial photograph as a light line forming the ridge.



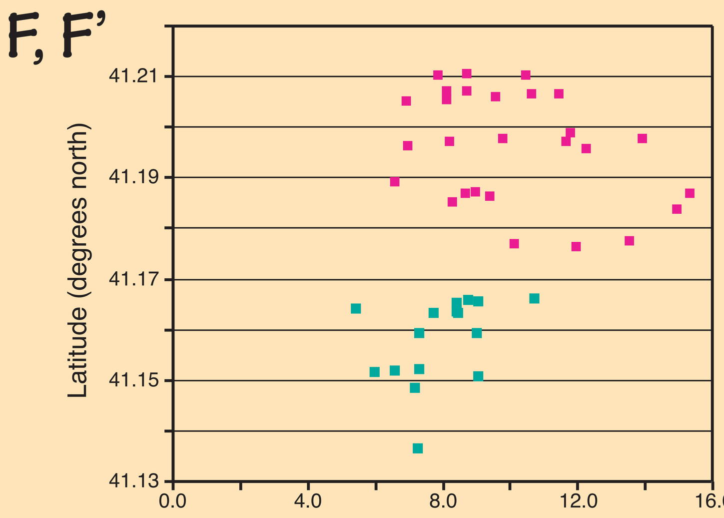
C

During one sampling trip in 1999, we observed a dramatic increase in the discharge of Osgood Creek as it crossed the Osgood Fault (green dashed line). At the same place, the conductivity decreased from >300 μS to 250 μS, documenting the discharge of ground water along the Osgood Fault.

B

Granite Creek flows to the SE, roughly along the probable trace of a major NW-trending structure. Neuerberg (1966) found an elongated zone of pyrite enrichment in the Osgood intrusive rocks along Granite Creek. From the upstream reaches to the downstream sample point, flow increased by more than 5 times, conductivity increased from 210 to 240 μS, and greater than 2x changes in concentrations were observed for Cl, B, K, Ba, Mg, Na, Sr, and Mn. No surface-water tributaries were observed along this reach of the stream. These changes are consistent with ground water discharge from altered rocks.

F, F'



There is a compositional difference in waters collected from the northern (pink squares) and southern (green squares) lobes of the Osgood intrusive rocks. Sulfur isotope data are shown above as an example, but many other dissolved constituents show a similar pattern, with a relatively narrow variability from southern-lobe samples and more extreme values in the northern lobe. We are investigating whether there is a similar variability in rock chemistry.

References:

Hotz, P. E., and Willden, R., 1964, Geology and mineral deposits of the Osgood Mountains quadrangle, Humboldt County, Nevada: U.S. Geological Survey Professional Paper 431.

Neuerberg, G.J., 1966, Distribution of selected accessory minerals in the Osgood Mountains stock, Humboldt County, Nevada: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-471.

Wanty, R.B., and Winter, T.C., 2000, A simple device for measuring differences in hydraulic head between surface water and shallow ground water: U.S. Geological Survey Fact Sheet FS-077-00.